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Nauka

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(54) **LIGHT EMITTING SYSTEM AND METHODS FOR CONTROLLING NANOCRYSTAL DISTRIBUTION THEREIN**

(75) Inventor: **Krzysztof Nauka**, Palo Alto, CA (US)

(73) Assignee: **Hewlett-Packard Development Company, L.P.**, Houston, TX (US)

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H01L 35/24 (2006.01)

(52) **U.S. Cl.** **257/40**; 257/E51.018; 257/E51.033; 257/E51.034; 257/E51.035; 257/E51.036

(58) **Field of Classification Search** 257/40, 257/E51.018, E51.033–E51.036
See application file for complete search history.

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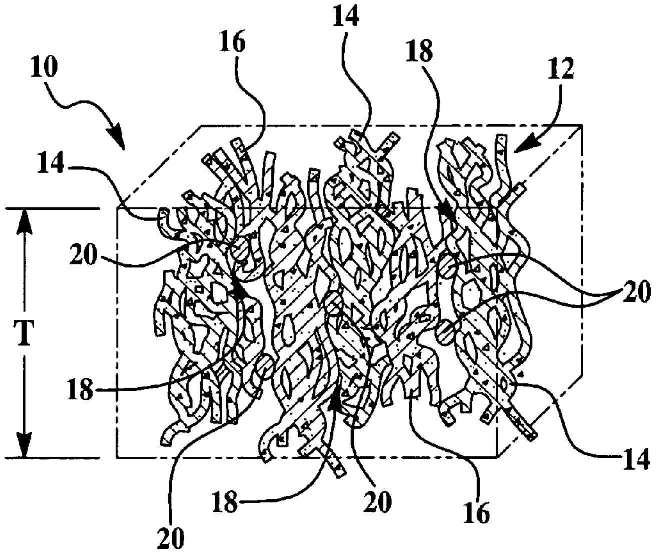
Primary Examiner—Kiesha R Bryant
Assistant Examiner—Minchul Yang

(57) **ABSTRACT**

A light emitting system includes a polymer mixture, and a plurality of nanocrystals occupying a predetermined portion of the polymer mixture. The polymer mixture includes at least two polymers that phase-segregate. Method(s) for controlling nanocrystal distribution within the light emitting device are also disclosed.

15 Claims, 4 Drawing Sheets



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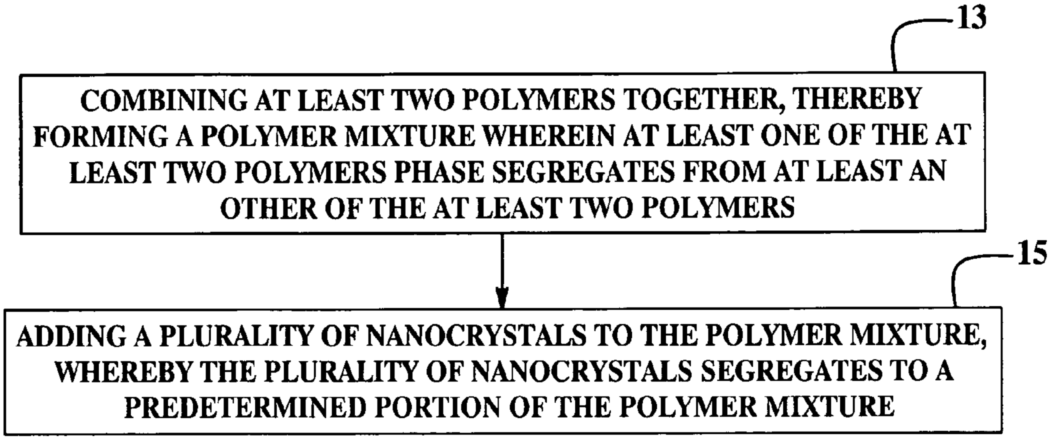

COMBINING AT LEAST TWO POLYMERS TOGETHER, THEREBY FORMING A POLYMER MIXTURE WHEREIN AT LEAST ONE OF THE AT LEAST TWO POLYMERS PHASE SEGREGATES FROM AT LEAST AN OTHER OF THE AT LEAST TWO POLYMERS

ADDING A PLURALITY OF NANOCRYSTALS TO THE POLYMER MIXTURE, WHEREBY THE PLURALITY OF NANOCRYSTALS SEGREGATES TO A PREDETERMINED PORTION OF THE POLYMER MIXTURE

FIG. 1

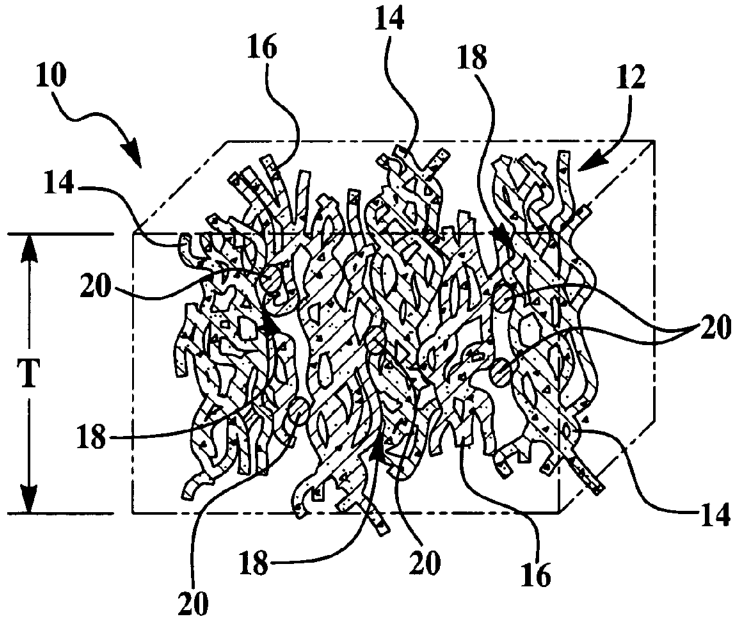

FIG. 2

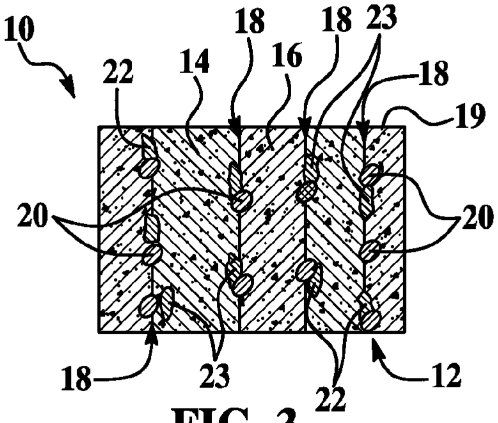

FIG. 3

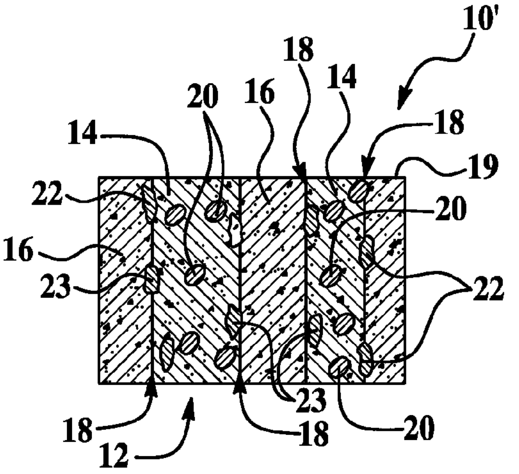

FIG. 4

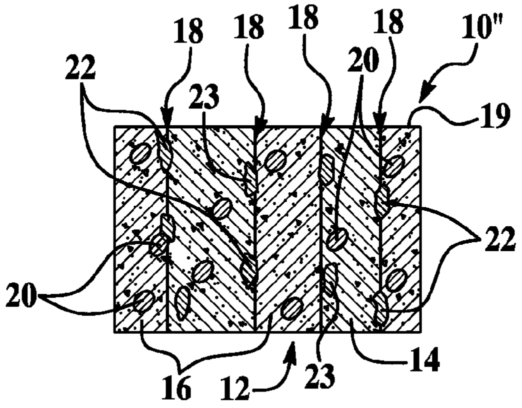

FIG. 5

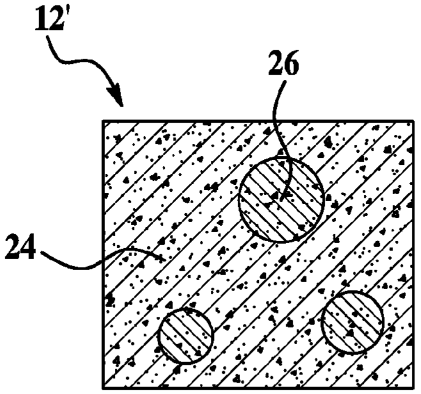

FIG. 6A

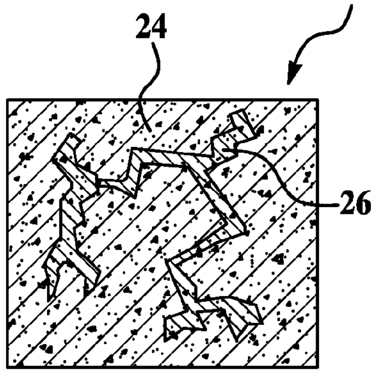

FIG. 6B

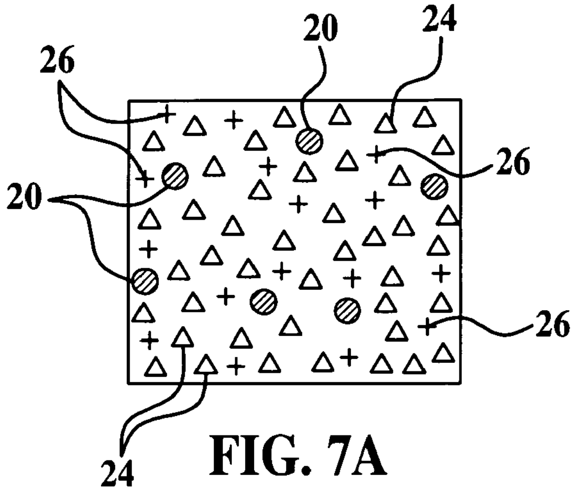

FIG. 7A

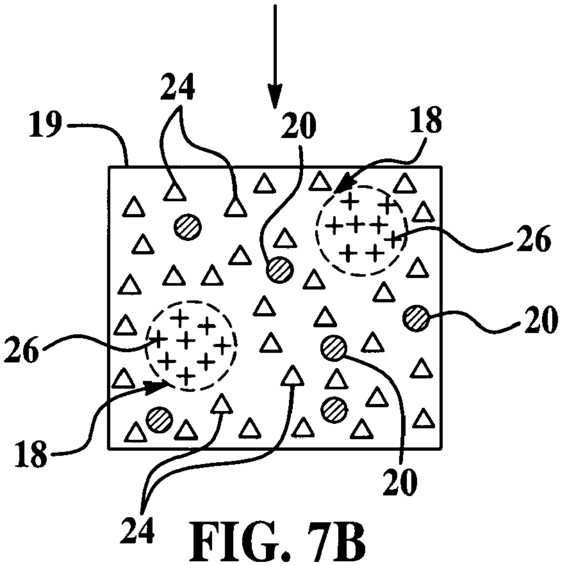

FIG. 7B

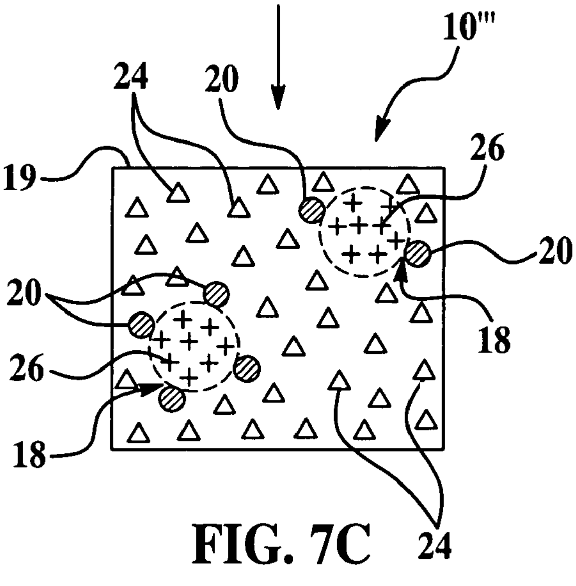

FIG. 7C

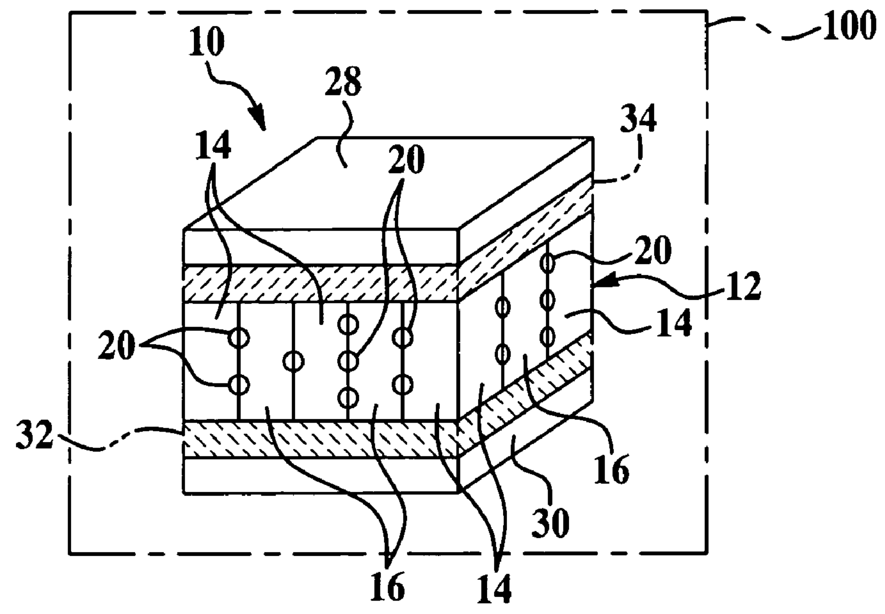
100
10
28
34
14
20
20
12
14
20
32
16
30
16
14

FIG. 8A

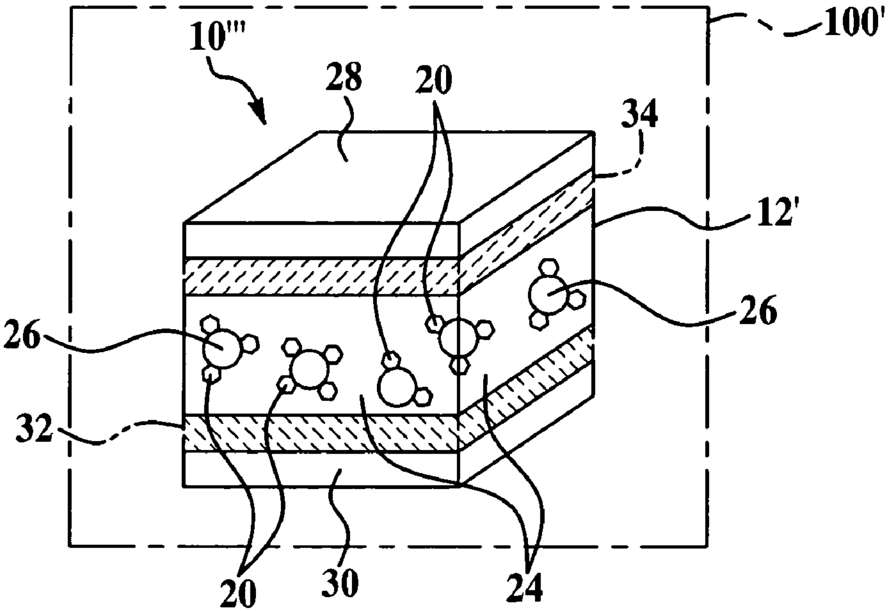
100'
10'''
28
20
34
12'
26
26
32
20
30
24

FIG. 8B

LIGHT EMITTING SYSTEM AND METHODS FOR CONTROLLING NANOCRYSTAL DISTRIBUTION THEREIN

BACKGROUND

The present disclosure relates generally to light emitting systems and methods for controlling nanocrystal distribution therein.

Hybrid light emitting systems combine inorganic nanocrystals and organic molecules. Such systems often include the organic polymer with the inorganic nanocrystals incorporated therein. The organic polymer/inorganic nanocrystal layer may be one of many stacked layers in such systems. Some light generation mechanisms are more efficient when the nanocrystals are present at specific location(s) within the layer. As an example, one mechanism may be more efficient when the nanocrystals are placed in the vicinity of one or both of organic excitons or exciplexes, while another mechanism may be more efficient when the nanocrystals are uniformly dispersed within the interfacial plane separating two organic layers. Inorganic nanocrystal and organic polymer systems tend to minimize their energy by redistributing the nanocrystals in a manner favorable for thermodynamic stability and potentially deleterious to hybrid device performance. As a result, nanocrystals tend to phase-segregate to the surfaces of the polymer layer, to form large aggregates within the polymer layer, or combinations thereof. Redistribution of nanocrystals after phase segregation or aggregation may not only reduce their ability to emit light, but it may also, in some instances, degrade the quality of the polymer.

Further, the polymer layer surface in light emitting systems often forms an interface with a metal established adjacent thereto. Segregation of nanocrystals to the polymer-metal interface may result in a parasitic energy loss mechanism, where the excited nanocrystal transfers its energy to the metal polarons before its radiative relaxation (and light emission) occurs. Nanocrystals at the polymer layer surface may also be removed or damaged as the subsequent layer (e.g., metal) is established on the polymer.

Attempts to reduce nanocrystal phase segregation include controlled removal of solvent from the polymer/nanocrystal layer, inhibiting nanocrystal movement via polymer structure, incorporating nanocrystal ligands that may improve the miscibility of the nanocrystals within the polymer layer, altering processing conditions, and forming chemical bonds between the nanocrystals and the polymers. The application and effectiveness of such techniques may undesirably be limited to specific nanocrystal concentrations and/or the polymer-nanocrystal combination.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of embodiments of the present disclosure will become apparent by reference to the following detailed description and drawings, in which like reference numerals correspond to similar, though not necessarily identical components. For the sake of brevity, reference numerals or features having a previously described function may not necessarily be described in connection with other drawings in which they appear.

FIG. **1** is a flow diagram depicting an embodiment of the method for controlling nanocrystal distribution within a light emitting system;

FIG. **2** is semi-schematic perspective view of an embodiment of a light emitting system;

FIG. **3** is a schematic cross-sectional view of an embodiment of an interpenetrating polymer network having nanocrystals segregated towards an interface between the polymers;

FIG. **4** is a schematic cross-sectional view of an embodiment of an interpenetrating polymer network having nanocrystals within one of the polymers;

FIG. **5** is a schematic cross-sectional view of an embodiment of an interpenetrating polymer network having nanocrystals within both polymers;

FIGS. **6**A and **6**B are schematic cross-sectional views of embodiments of a polymer mixture phase separated via nucleation and growth, and spinoidal decomposition, respectively;

FIGS. **7**A through **7**C schematically depict an embodiment of the method for controlling nanocrystal segregation in a phase separated polymer mixture; and

FIGS. **8**A and **8**B are semi-schematic perspective views of two embodiments of an emissive display device.

DETAILED DESCRIPTION

Embodiments of the method disclosed herein include controlling the distribution of nanocrystals within a mixture of polymers by employing non-miscible or partially miscible polymers. The method(s) disclosed herein advantageously allow nanocrystals to be segregated at an interface or throughout the polymer(s), and in the vicinity of excitons, exciplexes, or combinations thereof. Such nanocrystal segregation may be accomplished in polymer mixtures having a sufficient amount of nanocrystals to obtain relatively high intensity and light emission. Still further, embodiment(s) of the method advantageously segregate nanocrystals substantially without the formation of densely packed nanocrystals near the polymer mixture surface.

FIG. **1** depicts an embodiment of a method of controlling the nanocrystal distribution within a light emitting system. Generally, the method includes combining at least two polymers together to form a polymer mixture, as shown at reference numeral **13**; and adding a plurality of nanocrystals to the polymer mixture, as shown at reference numeral **15**. The distribution of the nanocrystal(s) throughout the polymer mixture may be controlled so that the nanocrystal(s) occupy predefined, discrete portions of the polymer mixture. The mixture includes at least two partially miscible or non-miscible polymers. Examples of polymers that phase segregate include, but are not limited to poly(9,9'-dioctylfluorene (PFO) mixed with poly(dioctylfluorene-alt-benzothiadiazole (F8BT), polyaniline (PANI) mixed with poly methylmethacrylate (PMMA). It is to be understood that these examples are non-limiting, and that other partially miscible or non-miscible polymer mixtures are contemplated as being within the purview of this invention.

Referring now to FIG. **2**, an embodiment of the light emitting system **10** is depicted. This embodiment of the light emitting system **10** includes a mixture **12** of polymers **14**, **16**, and a plurality of nanoparticles **20**.

In this embodiment, the properties and amounts of the polymers **14**, **16** are selected so that when mixed and phase separated they form an interpenetrating network of polymers **14**, **16**. It is to be understood that at least one of the polymers **14**, **16** is an electrical charge-conducting polymer. In an embodiment, one of the polymers **14**, **16** conducts both electrons and holes. In another embodiment, each of the polymers **14**, **16** is an electrical charge-conducting polymer. As a non-limiting example, one of the polymers **14**, **16** conducts electrons, and the other of the polymers **16**, **14** conducts holes.

It is believed that when the highest occupied molecular orbital (HOMO) and the lowest occupied molecular orbital (LUMO) levels of the two polymers **14**, **16** are selected, the polymer mixture **12** provides a network in which polymer excitons, exciplexes, or combinations thereof may be created when injected carriers, e.g., an electrical current, are added to the system **10**. In an embodiment, the polymer excitons and exciplexes are formed in the vicinity of interface(s) **18** between the two polymers **14**, **16**. Generally, the interface **18** is a surface that forms a common boundary between the two polymers **14**, **16**. It is believed that the three-dimensional nature of the interpenetrating network allows multiple interface(s) **18**, thereby allowing excitons, exciplexes, or combinations thereof to be formed throughout substantially the entire volume of the polymer mixture **12**.

The polymer mixture **12** may also include more than two polymers. In an embodiment, additional polymers may act as a scaffold in which the polymers **14**, **16** may be mixed. In another embodiment, the additional polymers may be used to increase or decrease the degree of phase separation between the polymers **14**, **16**. In still another embodiment, the additional polymers may be used to adjust potential barriers between the polymers **14**, **16** to enhance device performance.

In an embodiment, the polymer mixture **12** may be formed by dissolving the polymers **14**, **16** in a solvent, and establishing the polymer/solvent solution on a substrate. In another embodiment, the polymers **14**, **16** are established on a substrate, and then solvent is added, causing the polymers **14**, **16** to dissolve to form the polymer/solvent solution. It is to be understood that establishing the separate components (i.e., polymers **14**, **16** and then solvent) or the solution may be accomplished via any suitable method, non-limiting examples of which include spin-casting (e.g., for coating substantially the entire substrate), printing or stamping (e.g., for placing the polymer/solvent solution at desirable areas of the substrate), or the like, or combinations thereof. Prior to establishment of the polymers **14**, **16** and solvent, nanocrystals **20** may also be added to the polymer/solvent solution or to the polymers **14**, **16** prior to solution formation. In an embodiment, exposure to heat, solvent removal, or any other suitable method initiates the desired phase separation (non-limiting examples of which include the interpenetrating polymer network shown in FIG. **2**, and the embodiments shown in FIGS. **6**A and **6**B).

Suitable solvents include, but are not limited to a variety of organic solvents having a polarity that provides the ability to dissolve the polymers **14**, **16** while simultaneously rendering the desired behavior of the nanocrystals **20** within the solution.

In the embodiments disclosed herein, the miscibility of the nanocrystals **20** in the polymer mixture **12** depends, at least in part, on the surface chemistry of the nanocrystals **20**. The nanocystals **20** may include an inorganic core within which light generation processes take place. The nanocrystals **20** may also include an inorganic core with an inorganic shell covering the core. The inorganic core (e.g., in an embodiment when the nanocrystal **20** has no shell), or shell (e.g., in an embodiment when the nanocrystal **20** has a shell) may be coated with a layer of organic molecules, such as, for example, organic ligands. The ligands control interactions between the nanocrystals **20** and their surrounding environment, and they determine to what degree the nanocrystals **20** are miscible in a polymer. It is to be understood that the ligands may also impact the nanocrystal's ability to emit light.

FIGS. **3**, **4** and **5** depict various cross-sections of light emitting systems **10** including the interpenetrating polymer mixture **12** and nanocrystals **20** occupying predetermined portions of the polymer mixture **12**. The figures also depict the formation of excitons **22**, exciplexes **23**, or combinations thereof.

Specifically referring to FIG. **3**, the interpenetrating polymer mixture **12** has nanocrystals **20** occupying portions of the interface(s) **18** between the two polymers **14**, **16**. In this embodiment, the nanocrystals **20** are not miscible in either of the polymers **14**, **16**, and therefore they segregate toward nearby interfaces **18**, which provide low surface energy locations, rather than toward a surface **19** of the polymer mixture **12**.

The embodiment shown in FIG. **3** also depicts excitons **22** and exciplexes **23**, which singly or in combination are formed during operation of the system **10** or of a device incorporating the system **10** (e.g., when current is passed through the system **10**). In this embodiment, it is to be understood that the nanocrystals **20** will remain within the general vicinity of the formed excitons **22** and exciplexes **23**.

FIG. **4** depicts another embodiment of the light emitting system **10'**. In this embodiment, the interpenetrating polymer mixture **12** has nanocrystals **20** occupying the polymers **14**, **16**. In this embodiment, the nanocrystals **20** are selected so that they are miscible in one of the two polymers **14**, **16**. As such, the nanocrystals **20** will segregate to that particular polymer **14**, **16**. While FIG. **4** depicts the nanocrystals **20** being miscible in the polymer **14**, it is to be understood that the nanocrystals **20** may be selected to be miscible in the polymer **16**.

In this embodiment, the average cross-section of the polymer **14**, **16** having the nanocrystal(s) **20** miscible therein is relatively small (i.e., on the order of tens of nanometers). Without being bound to any theory, it is believed that this allows a majority of the nanocrystal(s) in the polymer **14**, **16** to be within the diffusion range of the excitons **22**, exciplexes **23**, or combinations thereof formed at the interface(s) **18** when the system **10'** is in operation. As previously described, excitons **22**, exciplexes **23**, or combinations thereof are formed when current is passed through the system **10'**.

FIG. **5** depicts still another embodiment of the light emitting system **10"**. In this embodiment, the interpenetrating polymer mixture **12** has nanocrystals **20** occupying both the polymers **14**, **16**. In this embodiment, the nanocrystals **20** are selected so that they are miscible in both of the polymers **14**, **16**. As such, the nanocrystals **20** will generally not phase segregate, rather they will remain within the polymers **14**, **16**.

In the embodiment depicted in FIG. **5**, the average cross-sections of particular segments of the polymers **14**, **16** are relatively small (i.e., on the order of tens of nanometers). Without being bound to any theory, it is believed that this allows a majority of the nanocrystals **20** in the polymers **14**, **16** to be within the diffusion range of the excitons **22**, exciplexes **23**, or combinations thereof formed at the interface(s) **18** when the system **10"** (or device in which the system **10"** is included) is in operation.

It is to be understood that other variations (beyond those shown in FIGS. **2**-**5**) of the nanocrystal **20** distributions within the light emitting system **10**, **10'**, **10"** are possible. A non-limiting example of such a variation includes a gradient of nanocrystal(s) **20** formed in at least one of the electron- or hole-conducting polymers **14**, **16** toward the interface(s) **18**. A gradient may be formed by using nanocrystals **20** that are partially miscible within one or both of the polymers **14**, **16**. Partial segregation may also be achieved by using a mixture of two types of nanocrystals **20**, one of which is miscible in the polymer(s) **14**, **16**, and the other of which is not miscible in the polymer(s) **14**, **16**. As a non-limiting example, partial segregation is accomplished using some nanocrystals **20** having ligands that favor phase segregation attached to the surface, and other nanocrystals **20** having ligands that favor mixing attached to the surface. Another non-limiting example of such a variation includes chemically bonding the nanocrystal(s) **20** to one or more of the polymers **14**, **16**.

As previously described, the interpenetrating polymer mixture **12** (shown in FIGS. **2**-**5**) includes multiple interfaces **18** between the polymers **14**, **16**. It is believed that the multiplicity of sides of interface **18** allows nanocrystals **20** to be distributed throughout the volume of the polymer mixture **12**. The thickness T (shown in FIG. **1**) of the polymer mixture **12** may be relatively large, as the thickness T is limited by the resistance of the polymer **14**, **16**. In an embodiment, the thickness T of the polymer mixture **12** ranges from about 10 nm to about 1000 nm. The thickness T enables a relatively large number of nanocrystals **20** to be distributed throughout the polymer mixture **12**. Embodiments of the light emitting system(s) **10**, **10'**, **10"** may advantageously achieve a relatively high emission intensity. This is due, at least in part, to the large number of nanocrystals **20** that may be included in the mixture **12** without overcrowding (which otherwise may lead to polymer degradation), maintaining an average distance between the nanocrystals **20** (thereby substantially avoiding deleterious nanocrystal-nanocrystal interaction), or combinations thereof.

Referring now to FIGS. **6**A and **6**B, other embodiments of the polymer mixture **12'** are depicted. Specifically, FIG. **6**A shows polymer **26** phase segregated from polymer **24** via a nucleation and growth mechanism; and FIG. **6**B shows polymer **26** phase segregated from polymer **24** via spinoidal decomposition. The different methods used may generally contribute to the different configuration (e.g., size, shape, etc.) of the phase segregated polymer **26**.

In these embodiments, the polymer mixture **12'** includes uneven amounts of two polymers **24**, **26**. The polymers **24**, **26** are partially or fully non-miscible, and tend to phase segregate. Generally, the polymer **26**, **24** that separates is incorporated in smaller amounts than the polymer **24**, **26** that acts as the matrix for the segregated polymer **26**, **24**. As shown in FIGS. **6**A and **6**B, if the mixture **12'** contains larger amounts of the polymer **24**, the polymer **26** separates to form inclusions of the polymer **26** within the polymer **24**. It is to be understood, however, that the amount of polymer **24** may be selected so that it forms inclusions within polymer **26**. As used herein, the larger amount of polymer (e.g., polymer **24**) is referred to as the "polymer matrix", while the smaller amount of polymer (e.g., polymer **26**) is referred to as the "polymer inclusions".

Generally, the phase segregated polymer inclusions (shown as **26**) have an arbitrary size (e.g., ranging from nanometers to microns). It is to be understood that additional polymers may be added to the mixture **12'** to assist in controlling the size and shape of the inclusions **26** in the matrix **24**.

In an embodiment, the polymer matrix **24** may be the nanocrystal **20** bearing component of the light emitting system **10'''** (shown in FIG. **7**C). As such, light generation may be contingent upon placing the nanocrystals **20** at specific locations within the polymer matrix **24**.

Polymer phase segregation may be accomplished via nucleation and growth (FIG. **6**A) or via spinoidal decomposition (FIG. **6**B). It is to be understood that the mechanism (i.e., whereby segregation occurs in the mixture **12**) of polymer phase segregation may be determined, at least in part, by the polymers **24**, **26** selected, the solvent removal conditions, the desirable shape of the polymer **26** inclusions, or the like, or combinations thereof.

FIGS. **7**A through **7**C illustrate an embodiment of forming an embodiment of a light emitting system **10'''** having the polymer mixture **12'** and nanocrystals **20** therein. It is to be understood that the phase segregated polymer mixture **12'** (shown in FIGS. **6**A and **6**B) advantageously allows for the distribution of the nanocrystals **20** at the interfaces **18** between polymer matrix **24** and polymer inclusions **26**. It is to be further understood that the distribution of nanocrystals **20** follows the distribution of the polymer inclusions **26** within polymer matrix **24**.

FIG. **7**A depicts the mixture of a larger amount of polymer **24** (represented by triangles), a smaller amount of polymer **26** (represented by crosses), and the nanocrystal(s) **20** (represented by circles) within a suitable solvent (not shown). Suitable solvents include, but are not limited to a variety of organic solvents having a polarity that provides the ability to dissolve the polymers **24**, **26** while simultaneously rendering the desired behavior of the nanocrystals **20** within the solution. As depicted in FIG. **7**A, the polymers **24**, **26** and the nanocrystal(s) **20** are randomly distributed throughout the solvent. While not shown, the polymer/nanocrystal/solvent mixture shown FIG. **7**A may be established on a substrate (not shown) as a layer or film. Alternatively, the polymers **24**, **26** and nanocrystals **20** may be established on the substrate and then have the solvent added thereto. In an embodiment, establishing, as previously described above in reference to FIG. **2**, may be accomplished via spin-casting, printing, stamping, or the like, or combinations thereof.

FIG. **7**B illustrates the mixture after the phase segregation process is initiated. As depicted, the polymer **26**, **24** substantially immediately begins to phase segregate from the polymer **24**, **26** to form the inclusions. It is to be understood that the concentration of the polymer **26**, **24** and the solvent removal conditions may be selected so that the average size of the phase segregated polymer **26**, **24** is relatively small, and the density is low enough to substantially not perturb the structural and electronic properties of the matrix polymer **24**, **26**.

The multiple interfaces **18** between the polymers **24**, **26** provide low free energy sites within the polymer mixture **12'**. At this stage (as depicted in FIG. **7**B), the nanocrystals **20** are still capable of moving within mixture **12'**, while attempting to minimize their energy. Since the interfaces **18** at the polymer matrix **24**—polymer inclusion **26** boundary are much closer than the surface **19** of polymer mixture **12'**, the majority of the nanocrystals **20** will remain within the bulk of the matrix **24** rather than aggregate at the surface **19** of the mixture **12'**.

FIG. **7**C depicts an embodiment of the light emitting system **10"** upon completion of phase segregation and nanocrystal **20** movement.

In the embodiment shown in FIGS. **6**A, **6**B and **7**A through **7**C, the phase segregating polymer **26**, **24** may be selected so that it does not substantially impact and/or impede the electronic processes taking place within the system **10'''**. Furthermore, the phase segregating polymer **26**, **24** may be selected so that it enhances the electronic processes taking place within the system **10'''**.

Referring now to FIGS. **8**A and **8**B, embodiments of the light emitting system **10**, **10'''** are shown incorporated into an emissive display device **100**, **100'**, respectively. It is to be understood that the light emitting system **10**, **10'**, **10"**, **10"** may be incorporated into any suitable display device **100**, **100'**.

As depicted, the light emitting system **10**, **10'**, **10"**, **10"** may further include top and bottom electrodes **28**, **30**, for supplying current to the system **10**, **10'**, **10"**, **10'"**. In an embodiment, the electrodes **28**, **30** may include, but are not limited to metals (non-limitative examples of which include aluminum, barium, lithium, gold, platinum, or the like, or combinations thereof), doped non-metals, organic materials, inorganic materials (a non-limitative example of which includes indium tin oxide), conducting polymers, or combinations thereof.

As depicted in these figures, the light emitting system **10**, **10'**, **10"**, **10"** may also include a blocking layer **32** between one of the electrodes **30**, **28** and the polymer mixture **12**, **12'**, and/or a blocking layer **34** between the other of the electrodes **28**, **30** and the polymer mixture **12**, **12'**. It is to be understood that such blocking layers **32**, **34** may be included to suppress parasitic leakage of currents(s) flowing throughout the polymer mixture **12**, **12'**.

Embodiments of the system **10**, **10'**, **10"**, **10"** and method disclosed herein include, but are not limited to the following advantages. The distribution of nanocrystals **20** throughout the polymer mixture **12**, **12'** may be controlled, at least by the selection of polymers **14**, **16**, **24**, **26**, nanocrystals **20**, solvent, or the like. The nanocrystals **20** advantageously segregate to predefined, discrete areas of the polymer mixture **12**, **12'** where they are in the vicinity of excitons **22**, exciplexes **23**, or combinations thereof formed during operation of the system **10**, **10'**, **10"**, **10'"**.

While several embodiments have been described in detail, it will be apparent to those skilled in the art that the disclosed embodiments may be modified. Therefore, the foregoing description is to be considered exemplary rather than limiting.

What is claimed is:

1. A light emitting system, comprising:

a polymer mixture including at least two partially miscible or non-miscible different polymers that segregate, the polymer mixture having a thickness ranging from about 10 nm to about 1000 nm; and

a controlled distribution of a plurality of nanocrystals occupying predefined, discrete positions of the polymer mixture, the controlled distribution being achieved due to properties of the at least two partially miscible or non-miscible different polymers selected for the polymer mixture and properties of the plurality of nanocrystals selected for the polymer mixture.

2. The light emitting system as defined in claim **1** wherein the polymer mixture includes a three-dimensional interpenetrating network of the at least two partially miscible or non-miscible different polymers, and wherein at least one of the at least two partially miscible or non-miscible different polymers conducts electrical charge.

3. The light emitting system as defined in claim **2** wherein each of the at least two partially miscible or non-miscible different polymers conducts electrical charge, wherein one of the at least two partially miscible or non-miscible different polymers conducts electrons, and wherein an other of the at least two partially miscible or non-miscible different polymers conducts holes.

4. The light emitting system as defined in claim **2** wherein the nanocrystals are not miscible in either of the at least two partially miscible or non-miscible different polymers, and wherein the controlled distribution includes at least some of the plurality of nanocrystals being located at an interface between the at least two partially miscible or non-miscible different polymers because the plurality of nanocrystals are not miscible in either of the at least two partially miscible or non-miscible different polymers.

5. The light emitting system as defined in claim **2** wherein at least some of the plurality of nanocrystals are miscible in at least one of the at least two partially miscible or non-miscible different polymers.

6. The light emitting system as defined in claim **2** wherein the controlled distribution includes a gradient of the plurality of nanocrystals formed in at least one of the at least two partially miscible or non-miscible different polymers towards an interface between the at least two partially miscible or non-miscible different polymers.

7. The light emitting system as defined in claim **1** wherein the polymer mixture includes three-dimensional discrete inclusions of one of the at least two partially miscible or non-miscible different polymers in an other of the at least two partially miscible or non-miscible different polymers, and wherein the controlled distribution includes at least some of the plurality of nanocrystals located at an interface between the discrete inclusions and the other of the at least two partially miscible or non-miscible different polymers.

8. The light emitting system as defined in claim **1** wherein the controlled distribution includes the plurality of nanocrystals located within a diffusion range of at least one of excitons, exciplexes, or combinations thereof formed when current is passed through the system.

9. The light emitting system as defined in claim **8** wherein the at least one of excitons, exciplexes, or combinations thereof are formed in a vicinity of an interface between the at least two partially miscible or non-miscible different polymers throughout a volume of the polymer mixture.

10. The light emitting system as defined in claim **8** wherein the excitons, the exciplexes, or the combinations thereof are configured to transfer energy into at least one of the plurality of nanocrystals.

11. The light emitting system as defined in claim **1** wherein at least one of the at least two partially miscible or non-miscible different polymers conducts holes, wherein at least one other of the at least two partially miscible or non-miscible different polymers conducts electrons, and wherein the polymer mixture further includes a scaffold polymer, a polymer configured to increase or decrease segregation of the at least two partially miscible or non-miscible different polymers, or a polymer configured to adjust a potential barrier between the at least two partially miscible or non-miscible different polymers.

12. The light emitting system as defined in claim **1** wherein the polymer mixture includes three-dimensional discrete inclusions of one of the at least two partially miscible or non-miscible different polymers in an other of the at least two partially miscible or non-miscible different polymers, and wherein the plurality of nanocrystals are miscible in one or the other of the at least two partially miscible or non-miscible different polymers.

13. The light emitting system as defined in claim **1** wherein the polymer mixture includes three-dimensional discrete inclusions of one of the at least two partially miscible or non-miscible different polymers in an other of the at least two partially miscible or non-miscible different polymers, and wherein the controlled distribution includes a gradient of the plurality of nanocrystals formed in one or the other of the at least two partially miscible or non-miscible different polymers towards an interface between the inclusions and the other of the at least two partially miscible or non-miscible different polymers.

14. The light emitting system as defined in claim **1** wherein the controlled distribution includes each of the plurality of nanoparticles being positioned an average distance from each other to substantially avoid nanocrystal-nanocrystal interaction.

15. A light emitting system, comprising:

a polymer mixture including at least two partially miscible or non-miscible different polymers that segregate, the polymer mixture having a thickness ranging from about 10 nm to about 1000 nm; and

a controlled distribution of a plurality of nanocrystals occupying predefined, discrete positions of the polymer mixture, the controlled distribution being achieved due to properties of the at least two partially miscible or non-miscible different polymers selected for the polymer mixture

wherein the controlled distribution includes the plurality of nanocrystals chemically bonded to at least one of the at least two partially miscible or non-miscible different polymers in the polymer mixture.

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